PHYLOGENETIC APPROACHES TO THE EVOLUTION OF COMPLEX ORGANISMS

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Cellular organisms are hierarchical entities: cells are composed of organelles, multicellular organisms of many cells, and so on. From its origin as a simple, single-celled prokaryote, the history of life has followed a trend toward increasing hierarchical complexity, taken here as the degree of nestedness of lower-level individuals within higher-level ones. What are the evolutionary mechanisms underlying this trend? Is there any upward tendency, such that increases are more likely than decreases, across the hierarchical spectrum? More generally, are there any universal rules of evolution that apply to all organisms, from simple cells to vast colonies? These questions have been difficult to address because the scale of analysis is necessarily so large. Also, these questions require some evidence for the evolutionary steps or transitions that occurred (i.e., changes from ancestors to descendants). Unfortunately, the fossil record contains little empirical evidence for these transitions. However, when evolutionary relationships are known or can be estimated, recently developed phylogenetic methods allow us to infer these ancestor-descendant transitions, and to test hypotheses about their evolution. Here we demonstrate the application of these phylogenetic methods with a recently completed study of the hierarchy trend. The standard interpretation would be that the trend is produced by a biased mechanism, in which increases in hierarchy are more likely than decreases, because increase is favored by natural selection. But a trend could also result from an unbiased, diffusive mechanism in which increases and decreases are about equally likely. In our study, transitions were inferred using previously published phylogenies of a wide range of organisms. In most cases, we failed to reject a null hypothesis of equal rates of hierarchical increase and decrease. In fact, a bias towards decreasing complexity was observed for several groups. In sum, results do not support the idea that increase in hierarchy is favored by selection. We also suggest related lines of research that could be pursued using these methods. For example, it has been suggested that as a new higher level arises, the lower-level entities that comprise it lose some of their hierarchical structure. Analyzing this in many groups would allow us to address whether this, or other similar phenomena have been pervasive throughout the "tree of life."